

ICD
for the
Hubble Robotic Vehicle Dexterous Robot



Goddard Space Flight Center
Greenbelt, Maryland

Table of Contents

1	Introduction	6
1.1.1	Purpose	6
2	Interfaces	7
2.1.1	On-orbit Segment Interfaces	7
2.1.1.1	Mechanical	7
2.1.1.1.1	DR to HRV	7
2.1.1.1.2	DR to GA	7
2.1.1.2	Electrical.....	7
2.1.1.2.1	DR to HRV	7
2.1.1.2.2	DR to GA	7
2.2	Design and Construction.....	8
2.2.1	Mass Properties	8
2.2.2	Power Consumption	8
2.2.3	Structural Design and Analysis	8
2.2.3.1	Load Cases	8
2.2.3.2	Safety Factors	8
2.2.3.3	Margins of Safety	9
2.2.3.4	Strength of Materials	9
2.2.3.5	Stowed Natural Frequencies	9

List of Tables

Table 1. Summary of States and Available Functions	10
Table 2.Payload Characteristics.....	10
Table 3.Launch Acceleration (ELV generic)	11
Table 4.Generalized ELV Random Vibration Test Levels (per GEVS-SE)	11
Table 5.Maximum Shock at the DR Interfaces.....	11
Table 6.Mass Budget	11

List of Figures

Figure 1. Avionics Electrical Interface	12
Figure 2.DR Quasi-Sinusoidal Vibration Spectrum.....	13
Figure 3.Maximum Shock at the DR Interfaces	14
Figure 4.Maximum Flight Level Acoustic Environment.....	15
Figure 5. DR Launch Configuration.	16
Figure 6. Dexterous Arm Launch Configuration.	17
Figure 7. DR Launch Tie-down locations.....	18

List of Appendices

Appendix A . Mechanical Layout.....	16
Appendix B . Specifications and Standards	19
Appendix C . Acronyms	20

1 Introduction

1.1.1 Purpose

This Interface Control Document (ICD) defines and controls the detailed designs of the Dexterous Robot (DR) to Grapple Arm (GA) interface necessary to assure form, fit and functional compatibility within the Hubble Robotic Vehicle (HRV) Program. The contents of this ICD are responsive to the applicable requirements of the DR to GA Interface Requirements Document (IRD-TBD).

The DR is comprised of the following major assemblies:

- a) Two Manipulator Arm Assemblies (MAAs) consisting of a Mechanical Arm (MA) which includes joints, booms, end effector, cameras and lights; Manipulator Control Avionics for manipulator control and vision processing; one grapple fixture and target for interface with the GA; and one Mechanical Body (MB) for mechanical connection of the MAAs, Avionics and GF.
- b) STARSS Ground Station (SGS) for planning and supervision of the robotic operations.

The Hubble Repair System architecture from the point of view of the DR is illustrated in Figure 1.

2 Interfaces

2.1.1 On-orbit Segment Interfaces

2.1.1.1 Mechanical

2.1.1.1.1 DR to HRV

- a) The stowed configuration of the DR shall not exceed the dimensions in Figure 7.
- b) The DR shall be attached and connected to the HRV via the interfaces defined in Figure 5.
- c) The DR shall be designed to survive launch loads (to be determined by the Customer in a coupled dynamic loads analysis) at the launch attachment points in Figure 7. The Customer is responsible for the design, production, installation and operation of the hold-down latches at the attachment points identified in Figure 7. Preliminary analysis will use the load factors defined in Table 3.

2.1.1.1.2 DR to GA

- a) The DR shall interface with the GA via the grapple fixture interface as shown in Figure 5.

2.1.1.2 Electrical

2.1.1.2.1 DR to HRV

- a) The DR shall receive 120V +/- 6V normal operating power from HRV.
- b) The DR shall be designed to receive thermal keep alive power at 28+/-6V received directly from the spacecraft power bus compliant with MIL-STD-461C.

2.1.1.2.2 DR to GA

- a) The DR shall interface with the GA via the interface defined in Figure 5.
- b) The DR shall be designed to operate at 120+/-6V received (via the GA) directly from the spacecraft power bus compliant with MIL-STD-461C.
- c) DR command, control and telemetry shall be transferred to and from the HRV via the DR Data Bus.
- d) The DR shall transfer Video image data to the HRV. Video may be transferred as an analogue NTSC signal or selected images may be captured, digitized, stored and transferred via a video data Bus.

2.2 Design and Construction

2.2.1 Mass Properties

The DR shall not exceed the mass budget in Table 6.

2.2.2 Power Consumption

The DR power source is 120V +/- 6V.

- a) The DR shall demand a maximum of 1700W average from the DR Operational Power input when the DR is powered but the MA is idle and the camera and lights are powered off.
- b) The DR shall demand a maximum of 2000W peak from the DR Operational Power input when the MA is not idle, and the camera and lights are powered on.
- c) The power demand from the DR Thermal Control Power input for survival shall not exceed 2000W peak and 500W orbital average.

2.2.3 Structural Design and Analysis

2.2.3.1 Load Cases

Four main load cases shall be considered in the structural analysis:

- a) Ground handling and test.
- b) Launch and ascent with the loads combined as follows:
 - i) acceleration combined with vibration (random or acoustic as applicable) in a root sum square fashion.
 - ii) thermal loads resulting from the liftoff thermal environment combined with the RSS sum of acceleration and vibration in an arithmetic fashion.
- c) The structural analyses will arithmetically combine thermal loads due to the operating thermal environment with dynamic loads as applicable.
- d) On-orbit or nominal operating loads which arithmetically combine cyclic orbital thermal loads with dynamic loads as applicable.

2.2.3.2 Safety Factors

Safety Factors shall be applied to the maximum predicted loads or stresses determined for the above load cases. The Safety Factors used in the stress analysis are:

- a) Verification by analysis
 - a) Considering yield strength: 2.00
 - b) Considering ultimate strength: 2.6
- b) Verification by test
 - c) Considering yield strength 1.25
 - d) Considering ultimate strength 1.40

2.2.3.3 Margins of Safety

The structural adequacy of each component will be determined by its Margin of Safety which is defined by the following equation:

$$MS = \frac{\text{Allowable Load or Stress}}{\text{Maximum Predicted Load or Stress} * SF} - 1$$

where: SF is the Safety factor

Allowable is the maximum permitted for yield, ultimate, buckling, etc.

Margins of Safety for each component shall be greater than or equal to zero.

2.2.3.4 Strength of Materials

The material properties used in the analyses shall be the minimum relevant values obtained through MIL-HDBK-5 or equivalent .

2.2.3.5 Stowed Natural Frequencies

The stowed manipulator shall have a natural frequency of at least 20Hz (TBR), when supported rigidly at the points defined in Figure 7, to avoid resonance with the main spacecraft vibration modes during launch.

Table 1. Summary of States and Available Functions

	Avionics Powered	MAA Thermal Control Active	MAA Telemetry Available	Software can be Uploaded/Initialized	Cameras and Lights available	Manipulator Motion Control Modes Available	Diagnostic Features Available
Off							
Initialize State	X	X		X			
Standby State	X	X	X		X		
Operate State	X	X	X		X	X	X

Table 2. Payload Characteristics

Parameter	Unit	Value
HRV Mass	Kg	6800 to 18000
HRV CoM relative to MAA base (x, y, z)	M	2 ± 0.5 , -0.5 ± 0.5 , 0 ± 0.5
HRV Inertias relative to COM (Ixx, Iyy, Izz)	Kgm ²	13000 to 55000, 14000 to 38000, 13000 to 55000
DR Payload Mass	Kg	550 maximum
DR Payload Inertias relative to GF (V1, V2, V3)	Kgm ²	500 maximum
DR Tool / Interface Adapter Mass	Kg	Enveloped by Payload Mass

Table 3.Launch Acceleration (ELV generic)

Case/ Axis	Maximum (Magnitude) Accelerations (g)
In any axis with 25% of primary load acting in remaining two orthogonal axes simultaneously	
Weight, lb	Load factor, g
<20	40
20-50	31
50-100	22
100-200	17
200-500	13

Table 4.Generalized ELV Random Vibration Test Levels (per GEVS-SE)

Frequency (Hz)	Acceleration Spectral Density (G^2)	Angular Acceleration Spectral Density (rd^2/s^4/Hz)
20	0.026	0.013
20-50	+6 dB/oct	+6 dB/oct
50-800	0.16	0.08
800-2000	-6 dB/oct	-6 dB/oct
2000	0.026	0.013
Overall	14.1 Grms	10.0 Grms

Table 5.Maximum Shock at the DR Interfaces

Frequency (Hz)	SRS Level (g's)
100	50
1,300	3,500
10,000	3,500

Table 6.Mass Budget

Assembly	Unit Mass (kg)	Quantity per System	Overall Mass (kg)	Notes
DR	1300	1	1300	Includes two MAs, avionics, body structure, two end effectors, grapple fixture, cameras, lights
Total			1300	

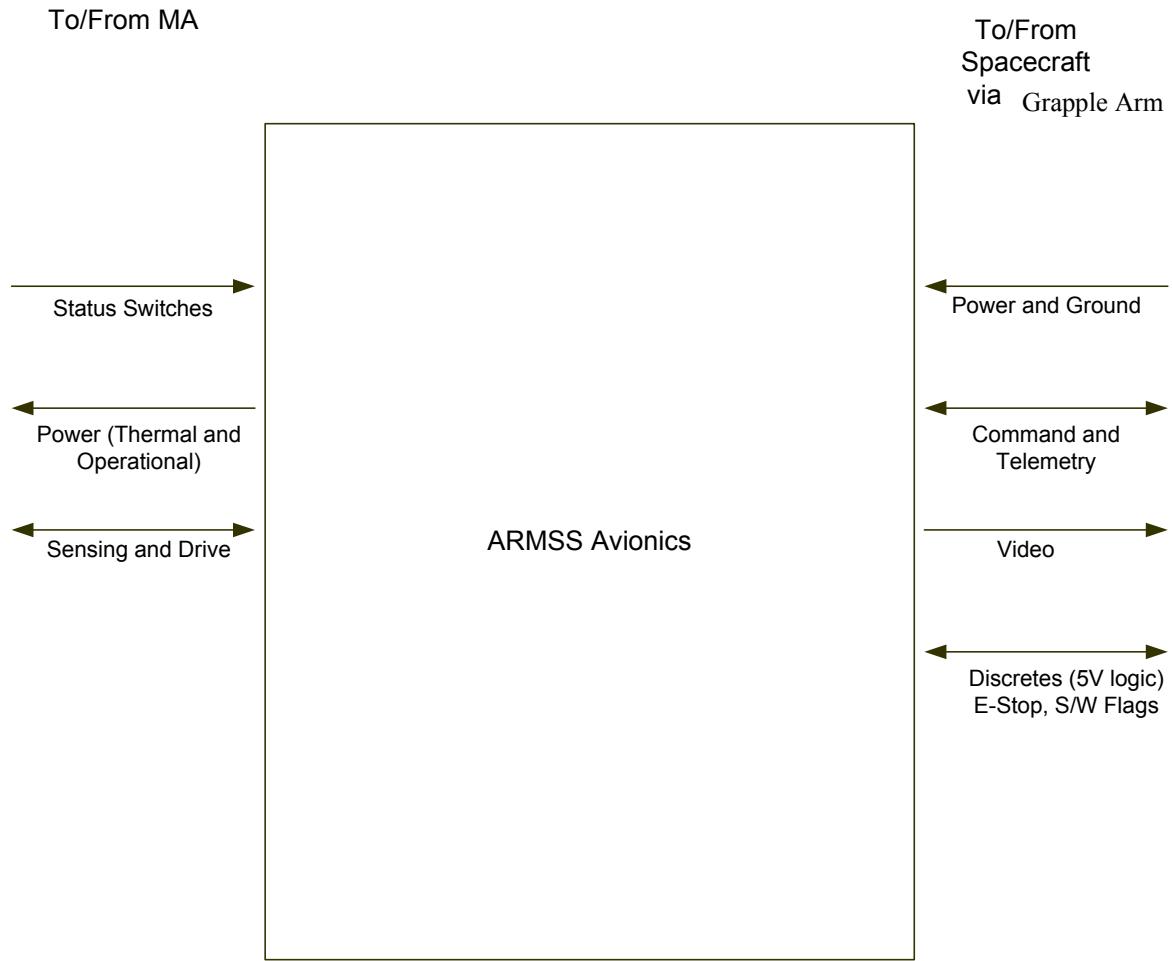


Figure 1. Avionics Electrical Interface

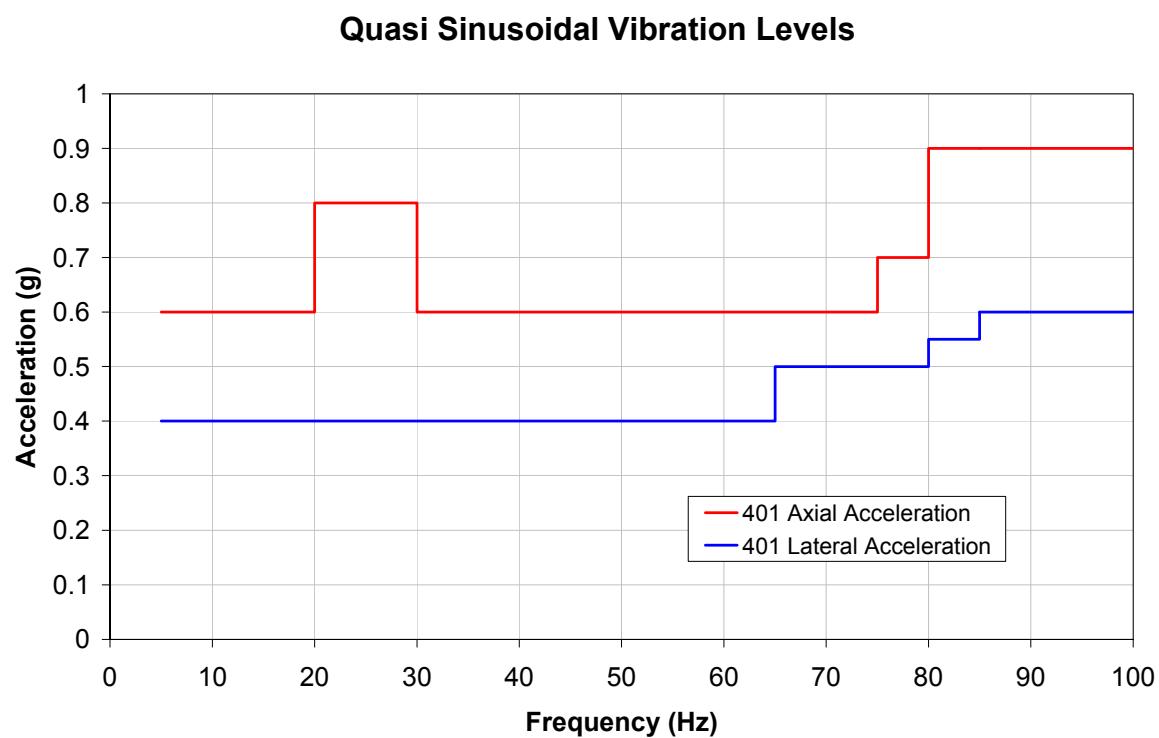


Figure 2.DR Quasi-Sinusoidal Vibration Spectrum

Maximum Flight Level Pyroshock at the Payload Interface

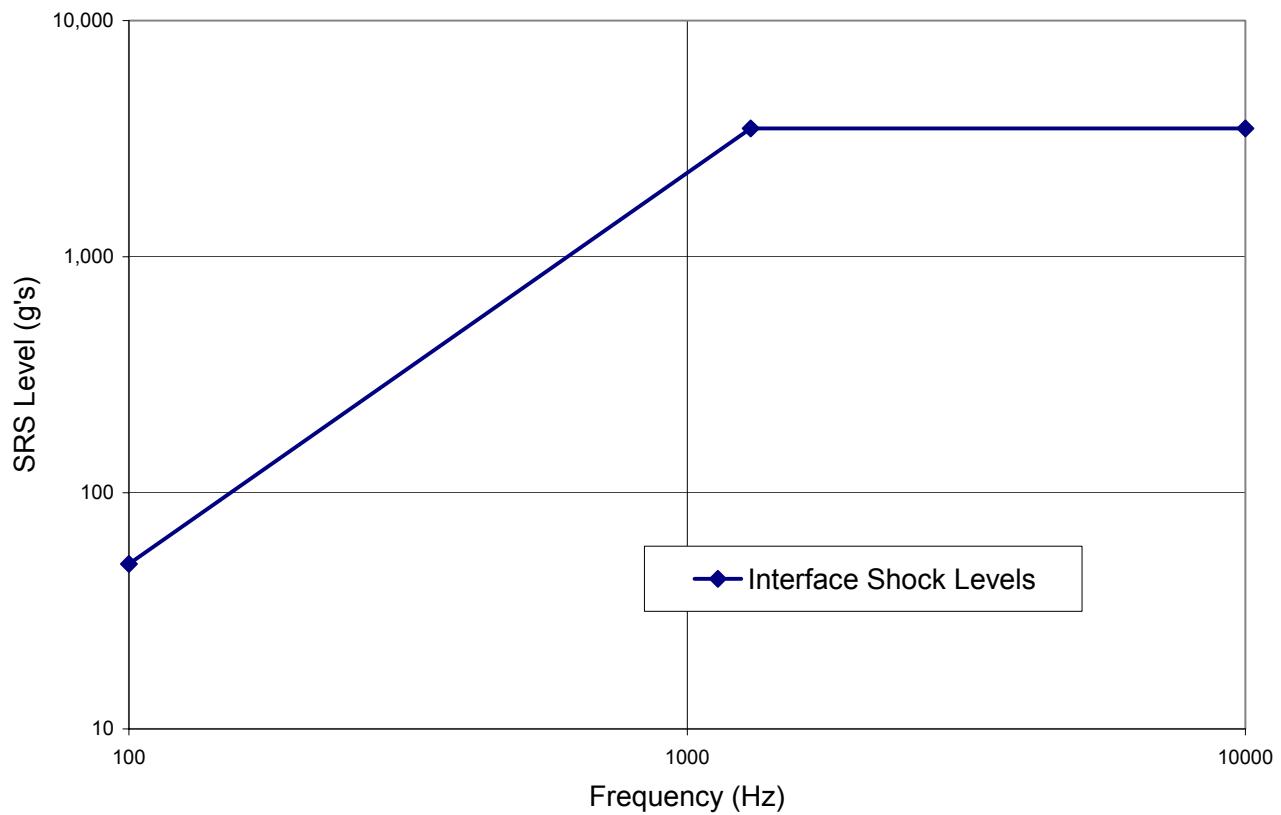


Figure 3. Maximum Shock at the DR Interfaces

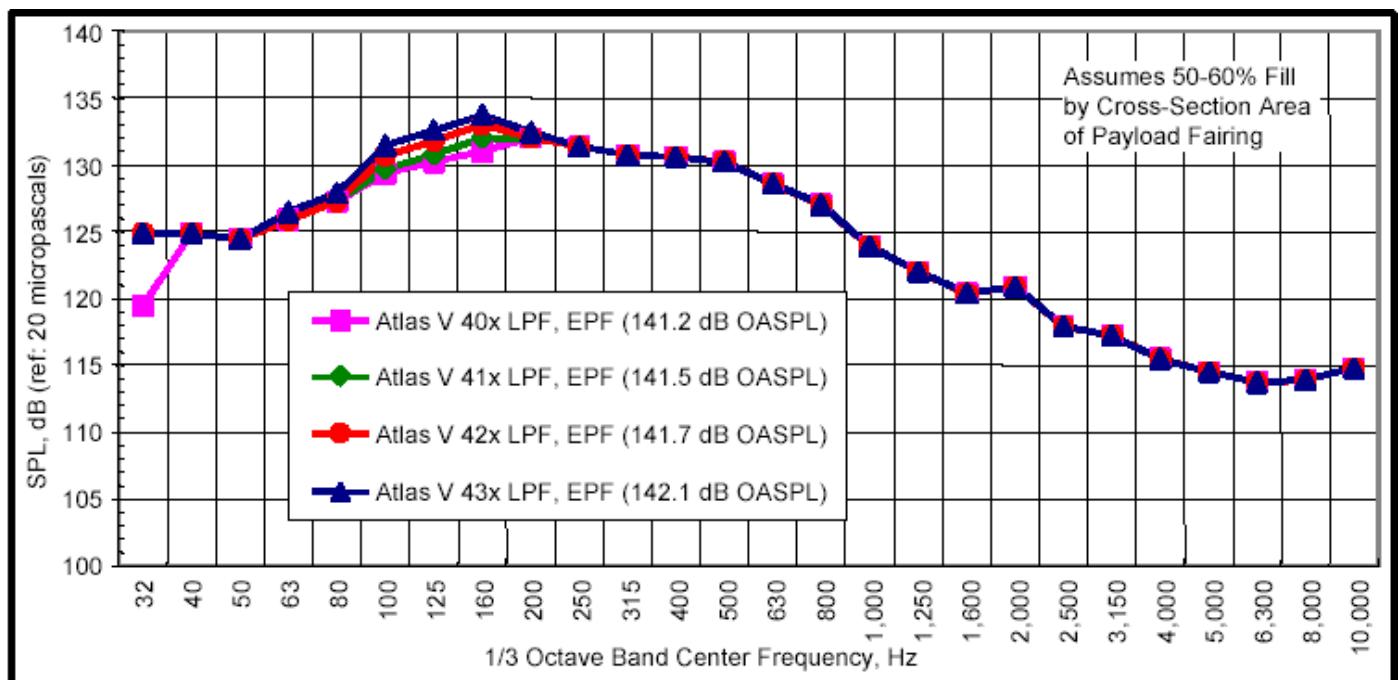


Figure 4. Maximum Flight Level Acoustic Environment

Appendix A. Mechanical Layout

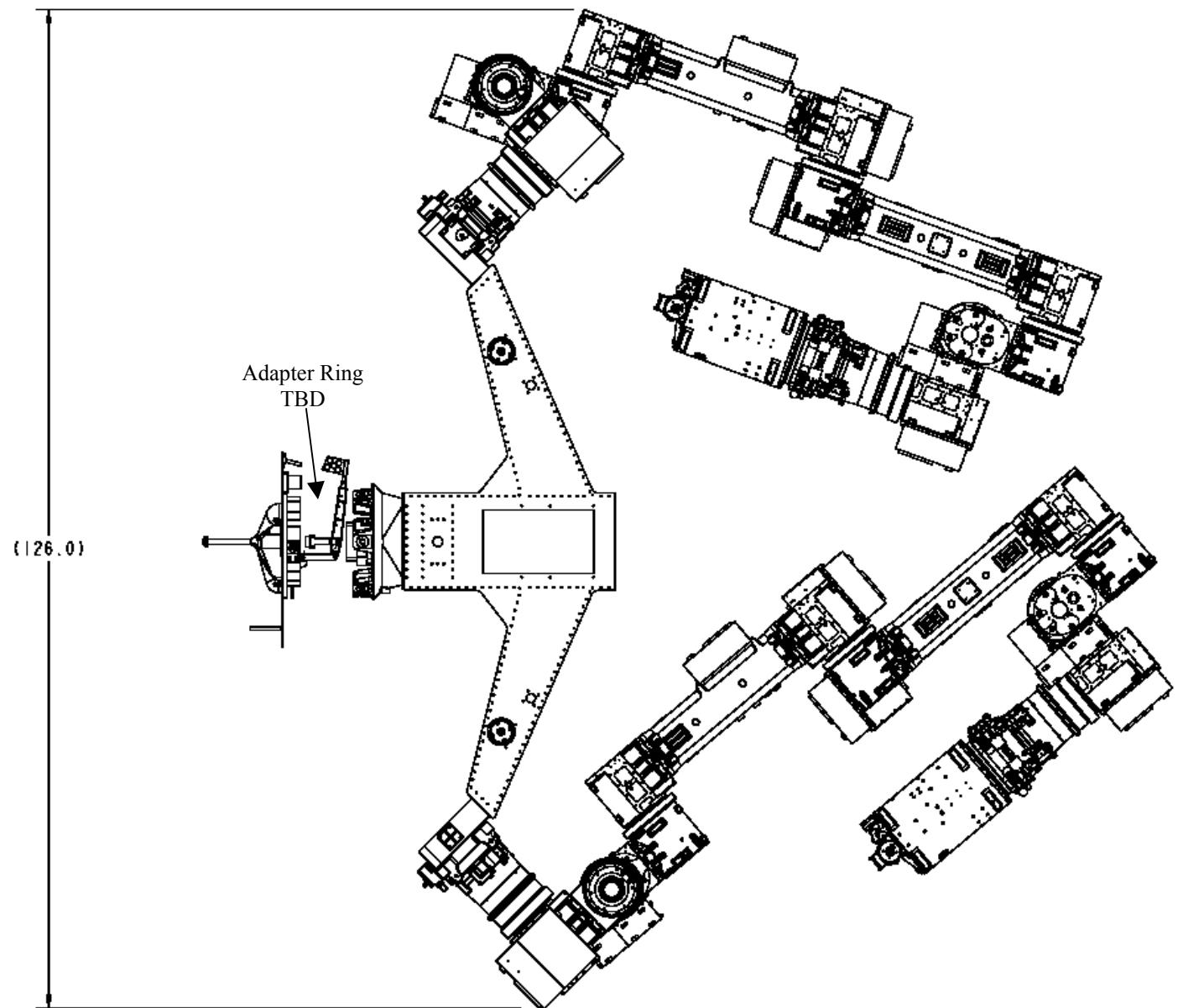


Figure 5. DR Launch Configuration.

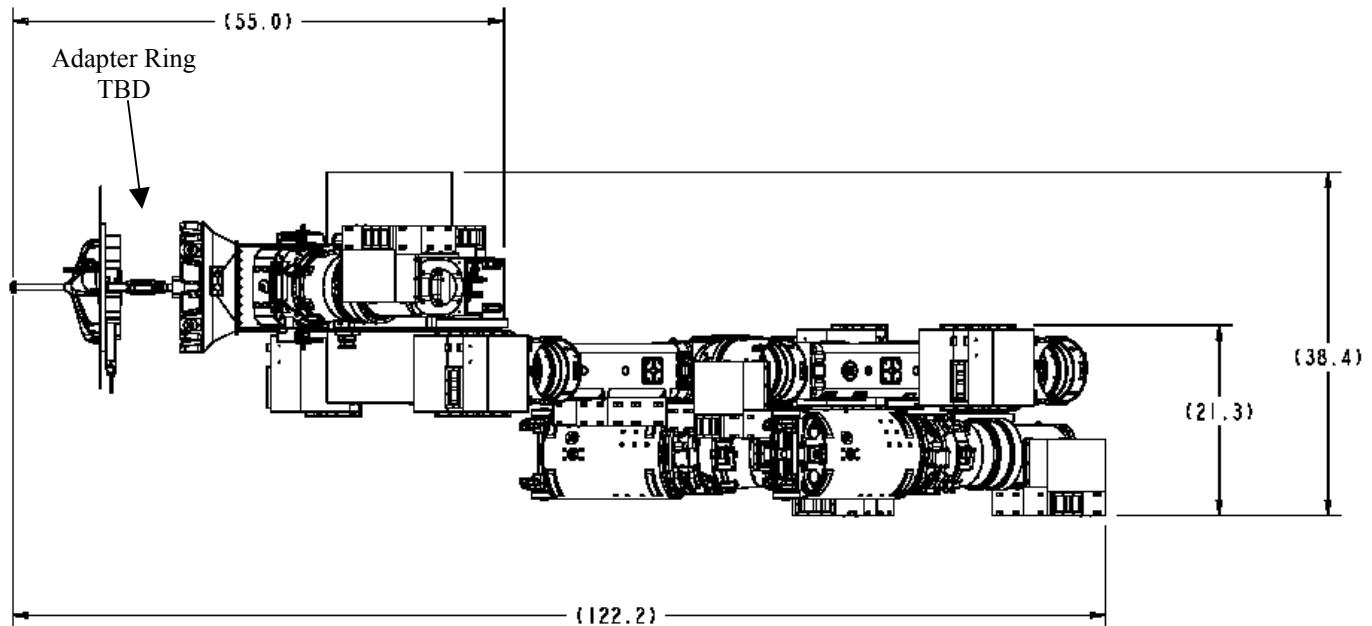


Figure 6. Dexterous Arm Launch Configuration.

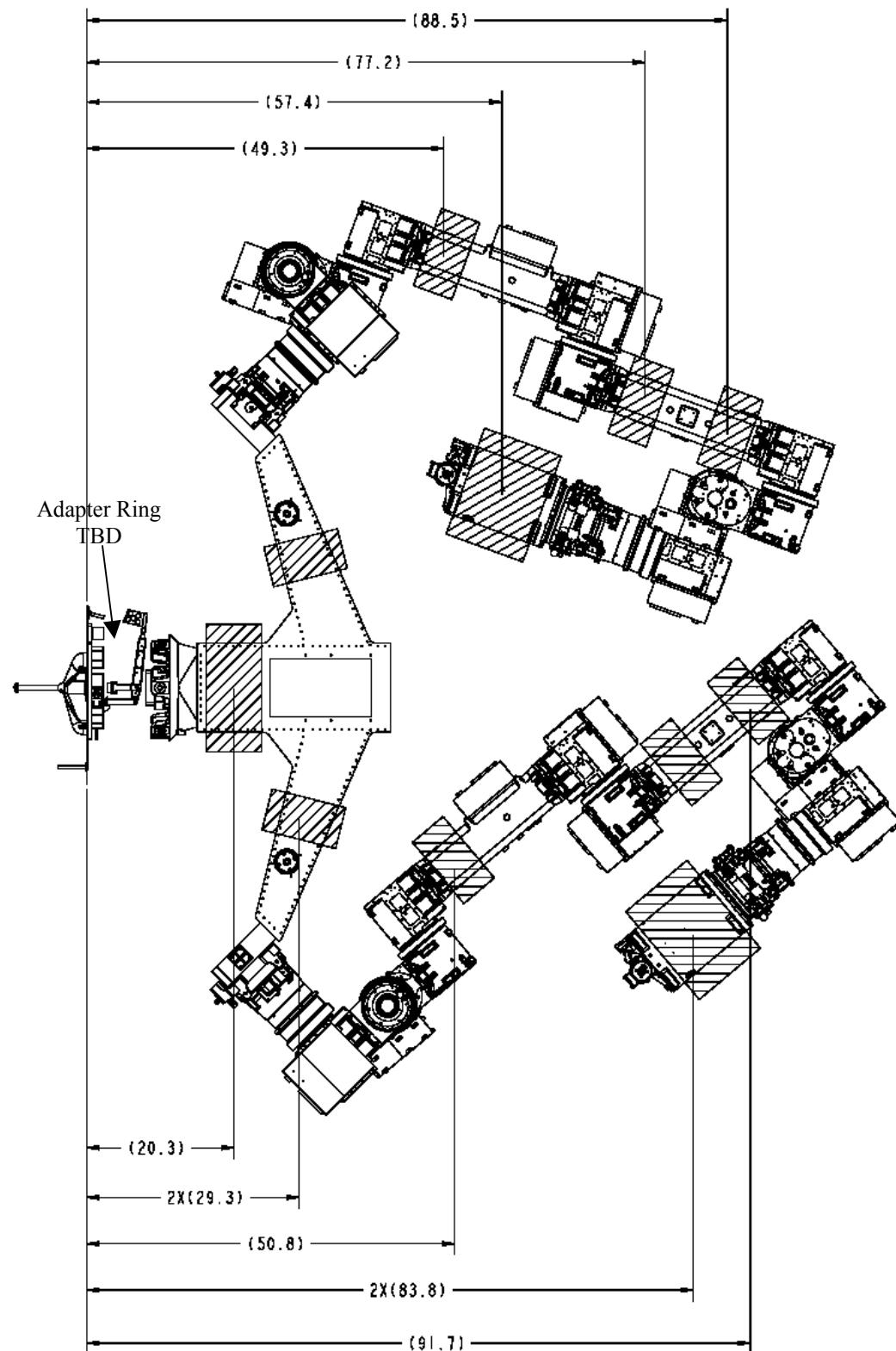


Figure 7. DR Launch Tie-down locations

Appendix B. Specifications and Standards

Document	Title
PE-PR.024E	Electrical, Electronic and Electromechanical Parts Reliability Program
MIL-HDBK-5	Materials and Processes
ISO/IEC 14772-1:1997	The Virtual Reality Modelling Language. International Standard (VRML97)
TIA/EIA-RS170A	Monochrome Television Studio Facilities, Electrical Performance Standards, Electrical Industries Association
MIL-STD-461C	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
TIA/EIA-422B	Electrical Characteristics of Balanced Voltage Digital Interface Circuits

Appendix C. Acronyms

COS	Cosmic Origins Spectrograph
COSTAR	Corrective Optics Space Telescope Axial Replacement
DR	Dexterous Robot
EMC	Electromagnetic Compatibility
HRV	Hubble Robotics Vehicle
GA	Grapple Arm
HST	Hubble Space Telescope
MA	Mechanical Arm
MAA	Manipulator Arm Assembly
MCU	Manipulator Control Unit
RSU	Rate Sensing Unit
SGS	STARSS Ground Segment
SPDM	Special Purpose Dexterous Manipulator
STARSS	Space Telescope Advanced Robotic Servicing System
WFC3	Wide Field Camera 3
WFPC2	Wide Field / Planetary Camera 2